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Evidence for the Origin of Organic Matter in the Solar System

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Beamline(s): X1A

Introduction: The origin of the organic matter in interplanetary materials has not been established. A variety of mechanisms have been proposed, with two extreme cases being a Fisher-Tropsch type process operating in the gas phase of the solar nebula or a Miller-Urey type process, which requires interaction with an aqueous fluid, presumably occurring on an asteroid. In the Fisher-Tropsch case, we might expect similar organic matter in hydrated and anhydrous interplanetary materials. However, aqueous alteration is required in the case of the Miller-Urey process, and we would expect to see organic matter preferentially in interplanetary materials that exhibit evidence of aqueous activity, such as the presence of hydrated silicates. The types and abundance of organic matter in meteorites have been used as an indicator of the origin of organic matter in the Solar System. However, all anhydrous carbonaceous chondrite meteorites are significantly depleted in the moderately volatile elements compared to the “solar” composition. The high temperature (>1200 C) proposed to explain the volatile depletion is sufficient to remove or destroy most volatile organic matter in the anhydrous meteorites, *indicating that the meteorite studies do not constrain the origin of organic matter.*

Methods and Materials: Many anhydrous interplanetary dust particles (IDPs), dust from comets and asteroids collected from the Earth’s stratosphere, have volatile contents higher than the hydrated carbonaceous meteorites, suggesting these IDPs experienced minimal thermal processing. Unequilibrated mineralogy and high D/H spots within micrometers of regions with normal D/H further demonstrates that many IDPs never experienced significant heating. We employed the Scanning Transmission X-Ray Microscope (STXM) on Beamline X1A to infer the origin of organic matter in the Solar System by measuring the abundance and types of carbon in *all three kinds* of primitive (not thermally processed) extraterrestrial materials available for laboratory analysis: anhydrous IDPs, hydrated IDPs, and hydrated carbonaceous chondrite meteorites.

Results: The 3 hydrated IDPs and 7 of the 9 anhydrous IDPs we examined using the STXM have essentially identical C- X-ray Absorption Near Edge Structure (C-XANES) spectra, and these spectra are generally similar to the C-XANES spectrum of acid-insoluble organic matter extracted from Murchison, a hydrated carbonaceous chondrite meteorite (see Figure 1). Each of these C-XANES spectra shows a strong absorption at ~285 eV, characteristic of the C-ring functional group, and a second strong absorption at ~288.5 eV, characteristic of the C=O bond (and distinct from the ~290 eV absorption of the C-O in carbonate). The C=O detection indicates a substantial fraction of the carbon is organic rather than elemental or mineralogical. The rough equivalense in the relative strengths of these two absorptions in the three types of samples indicates that the C-ring to C=O ratio is similar in all three materrials.

Conclusions: The similarity of the C-XANES spectra of anhydrous IDPs, hydrated IDPs, and hydrated carbonaceous meteorites as well as the high (percent-level) organic carbon content of anhydrous IDPs are *consistent with the production of much of the organic matter prior to incorporation into the asteroids.*

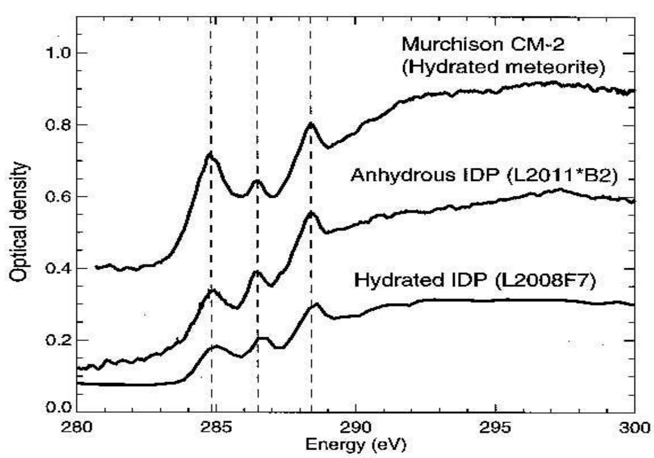

Figure 1: C-XANES spectra of the Murchison carbonaceous chondrite meteorite, and anhydrous IDP, and a hydrated IDP.